Weapons Effects in Urban Terrain

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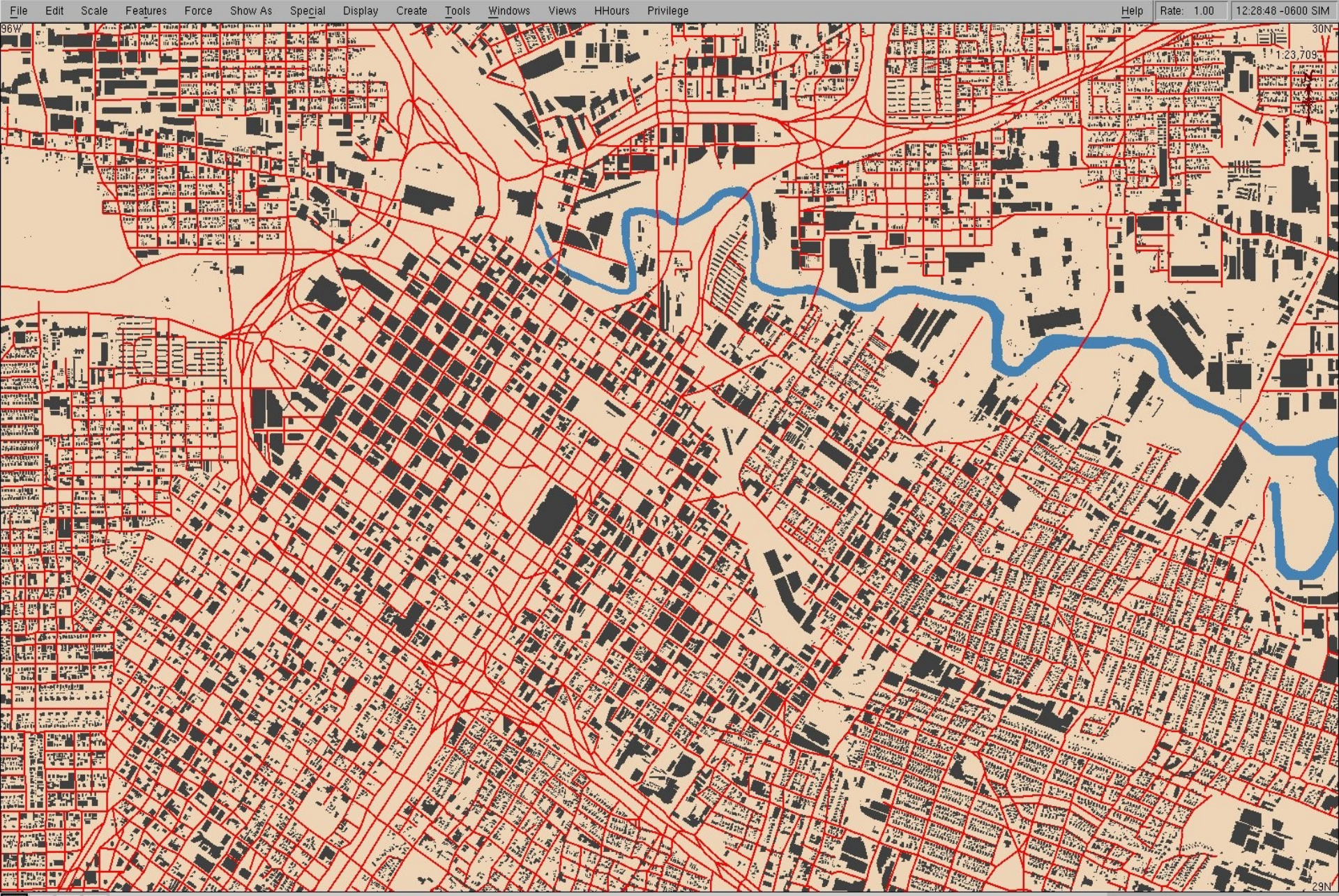
Simulation of Urban Operations

- Simulation in urban areas is of critical importance to
  - PEO STRI, RDECOM
  - JFCOM (J9 JUO)
  - JNTC
  - ONR (VIRTE)
  - AMSO (MOUT FACT)
- Operations
  - Building clearing operations
  - Cover and concealment
  - Dynamic changes: mouseholes, loopholes, fortification with sandbags, ….

Most Urban Databases Relatively Small in Geographic Extents

- Customers want real cities
  - OOS requires populating at City Graphics scale (1:12,500)
  - Joint Experimentation (J9) JFCOM wants even more detail
    - Urban clutter: sheds, dumpsters, telephone poles, wires, etc.
- Houston experiment (J9 funding)
  - Extruded 650,000 building features from geospecific footprints
  - Generated CTDB and visual
  - The largest density to size ratio of any CTDB


File
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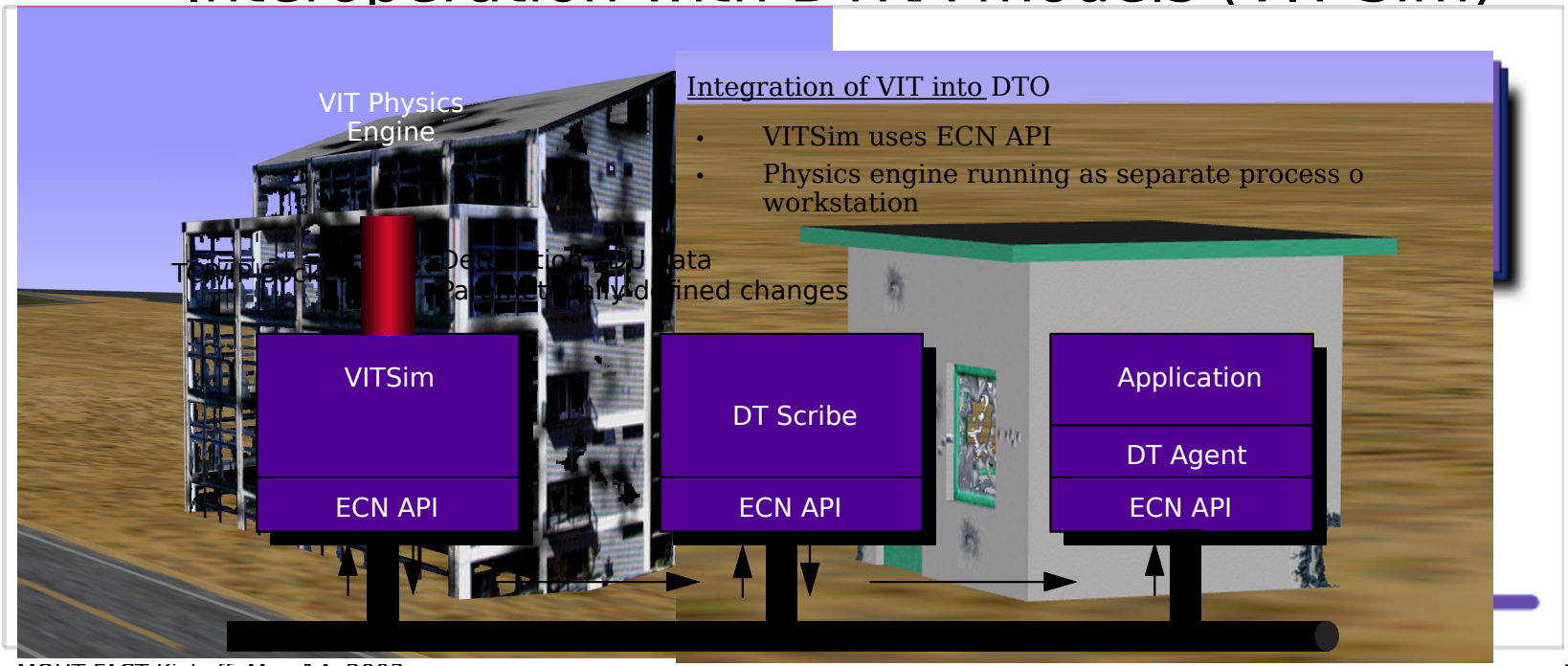
96W
30N
1:23,709
29N
Zoom: click middle to zoom in around point; click right to zoom out around point; click and drag middle to set screen area
L/L
29°44'29.96"N
95°20'53.87"W
Select an item to edit

Prior Efforts (1/2)

- DARPA STOW 97 ACTD
  - Dynamic Terrain (DT) Architecture
  - Model switching (multi-state objects)
  - Demonstrations of building repolygonization
  - Interoperation with DTRA models (VIT-Sim)

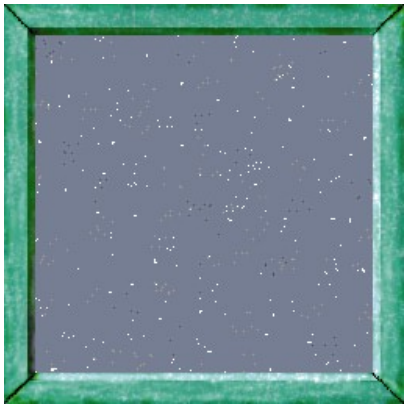


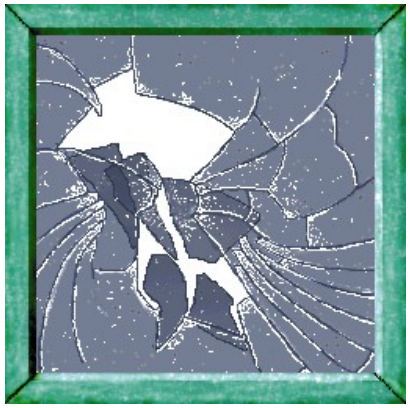
Prior Efforts (2/2)

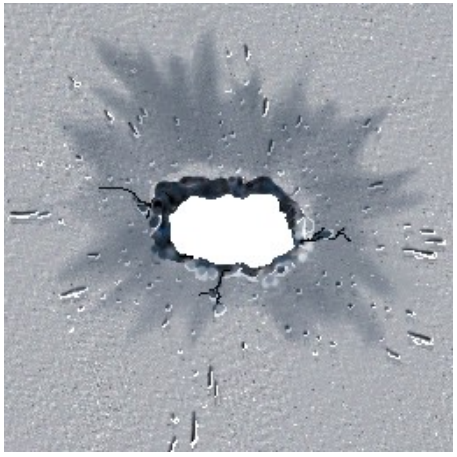
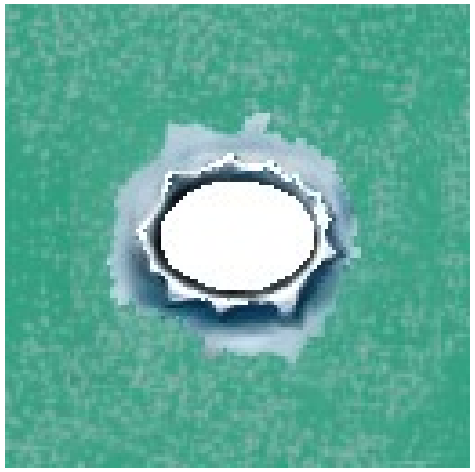
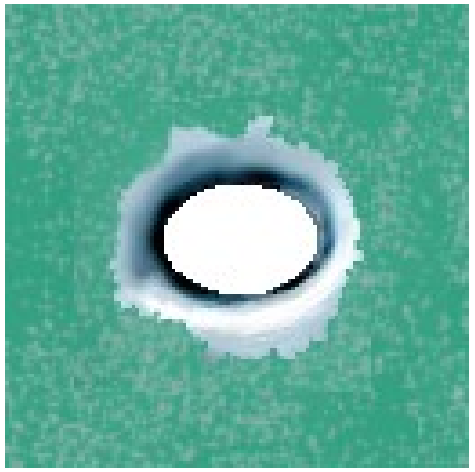
- DTRA contractors used BRL-CAD to model buildings for damage assessment using physics-based models
  - Still needed polygonal representation for visualization
  - Entire process could require several minutes
- DI SAF Hole Server
  - Medium munitions open apertures
  - Large munitions create mouseholes

From ct_apert.c in function ctdb_mes_create_aperture :

/* $$$ The first time this is done, it works fine because the data for the boxes is just in the memory-mapped TDB. However, the generate_boxes function allocates memory for new box data (triangle ID arrays, etc.). Thus if a second hole is blown in the same MES there will be a big memory leak since none of that data is deallocated here. */





Requirements

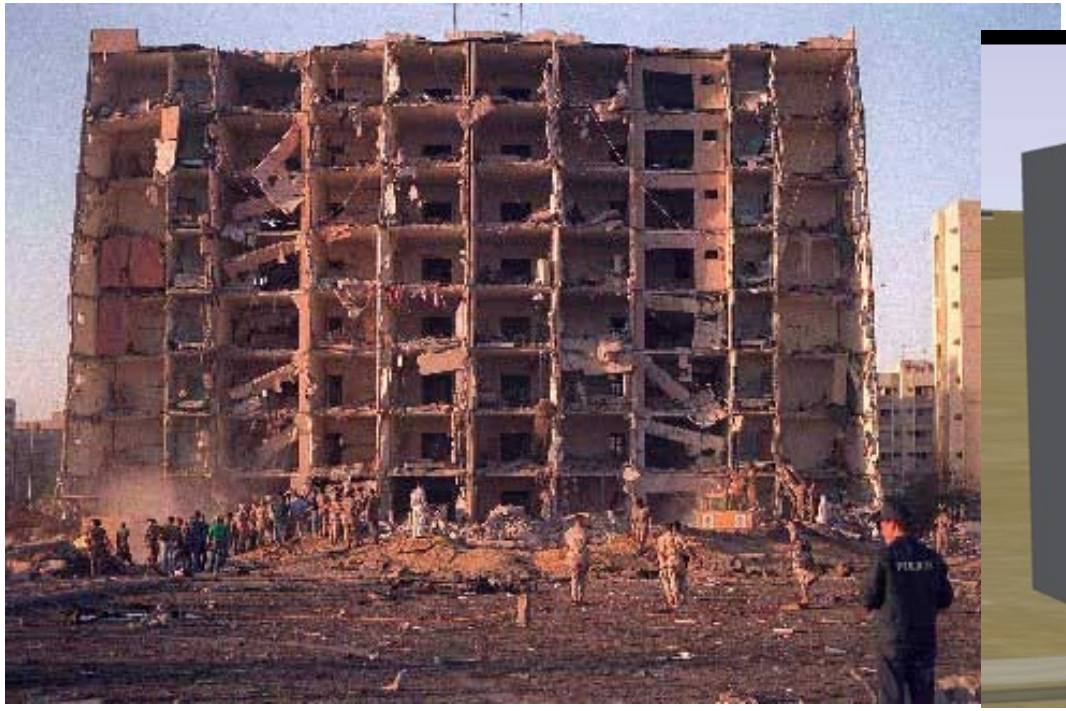
- Holes in walls
- Rubble
- Wire netting on windows
- Fortification of walls with wood or other materials
- Removing stairs
- Holes in floors (with ladders)
- Sandbags
- Damage to underground bunkers from penetrating munitions

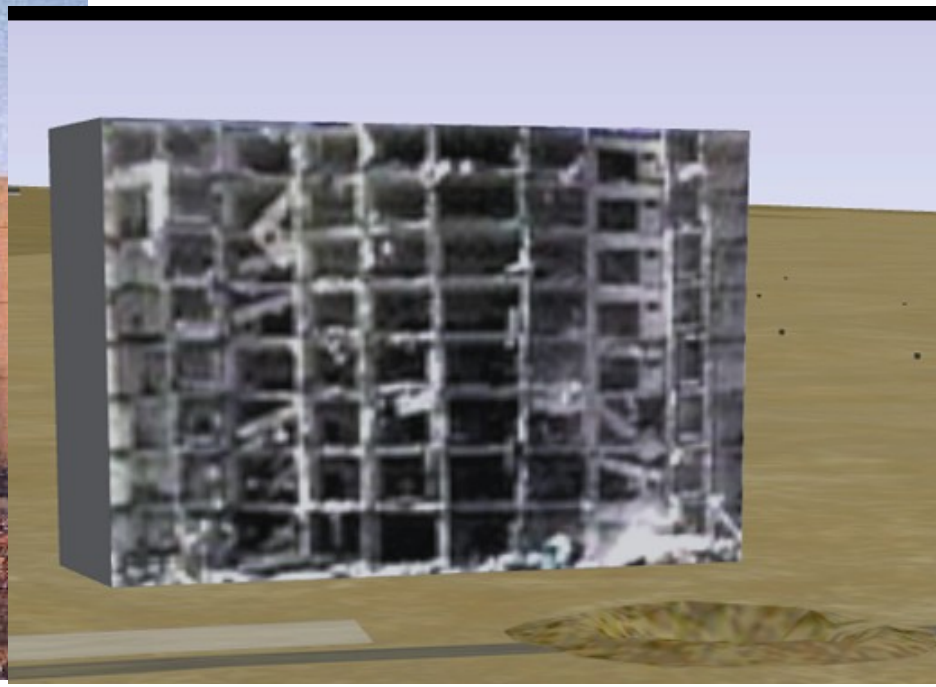
J9 OpFor Requirements

- Three distinct elevations
  - Ground level
  - Below ground (Sewers, subways, overpasses, RR tunnels, regime specific or mission specific caves or bunkers or communications tunnels)
  - Multi-storied structures
- Buildings
  - Ability to fight from floors 1 thru 3 and roof.
    - Ability to camouflage firing position on a roof to mimic roof-like characteristics (roofing material or shed roof etc.)
  - Varying degrees of structural protection (cover)
    - Ability to improve protection level (sandbags)
  - Ability to see from interior without being exposed
  - Ability to fire weapons from interior without exposing firer
  - Ability to connect adjacent buildings by knocking holes in interior walls to create covered passageways
  - Ability to create concealed routes connecting blocks of buildings
  - Ability to move large vehicles into some subset of buildings (e.g. large garages or warehouses)
  - Ability to blast openings in some buildings large enough to back in a large vehicle (e.g. tank)

A Continuum of Possible Damage States

- From simple hole in a wall to complete destruction of the building
  - Both are relatively simple
  - It’s the continuum in the middle that’s hard





Why Constructive Solid Geometry?

- Damage to a building depends on building configuration and construction type
  - Pressure wave and overtemperature conditions propagate through enclosures and apertures
    - Modeling as a bag of polygons ignores building configuration
  - VIT-Sim required analysis of building construction plans
- But CSG is computationally expensive
- Need cheaper way to encode building configuration and attribution ….

EDM-UHRB

- Requirements
  - ORD not specific
  - TEMO: training command vs. squad level
    - Use case: small force clearing single building
  - Solicited requirements from Combined Arms MOUT Task Force (CAMTF), Infantry Center, Ft. Benning
- Results: need rooms, floors, walls, windows, doors, furniture, basements, attics, shafts, ducts, stairs, breach holes, wall fortification, ….

UHRB Objectification

- Added generalization features
  - Inheritance of attribution
  - Inheritance of relationships
  - Multi-level hierarchy
- Examples
  - Building has layers
  - Layers have compartments
  - Compartments have horizontal and vertical partitions
  - Partitions have openings
  - Layers are connected by vertical passages

UHRB Attributes

- Categories of attributes
  - Human mobility
  - General geometry
  - Material composition
  - Construction type
  - Visual and thermal characteristics
  - Information to support breaching and damage assessment

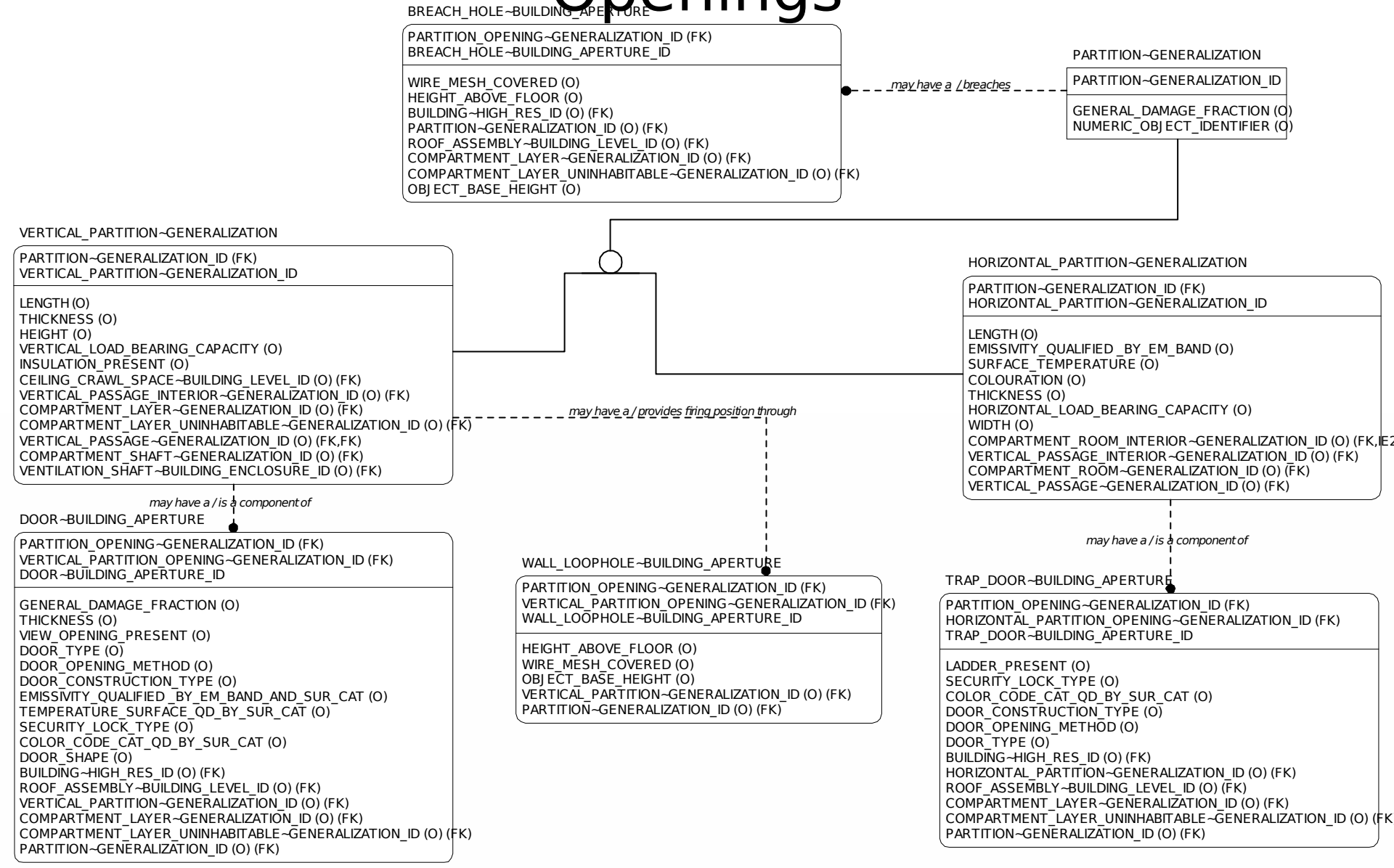
Example: Attributes of EXTERIOR_WALL

EXTERIOR_WALL_CONSTRUCTION_TYPE
EXTERIOR_WALL_FORTIFICATION
GENERAL_DAMAGE_FRACTION
HEIGHT
LENGTH
NUMERIC_OBJECT_IDENTIFIER
THICKNESS
VERTICAL_LOAD_BEARING_CAPACITY
INSULATION_PRESENT
COUNT_QD_BY_BCT_FOR_EXTERIOR_WALL
EMISSIVITY_QUALIFIED _BY_EM_BAND_AND_SUR_CAT
SUR_MAT_TYPE_QD_BY_SUR_CAT
COLOURATION_QD_BY_SUR_CAT
SURFACE_TEMPERATURE_QD_BY_SUR_CAT

UHRB Relationships

- Building “assembled” from its components via relationships
  - Buildings have layers,
  - layers have rooms,
  - rooms have walls, floors and ceilings,
  - walls may have doors,
  - exterior walls may have windows,
  - floors may have trap doors,
  - ceilings may have skylights and trapdoors

Example IDEF1X – Partitions and Openings



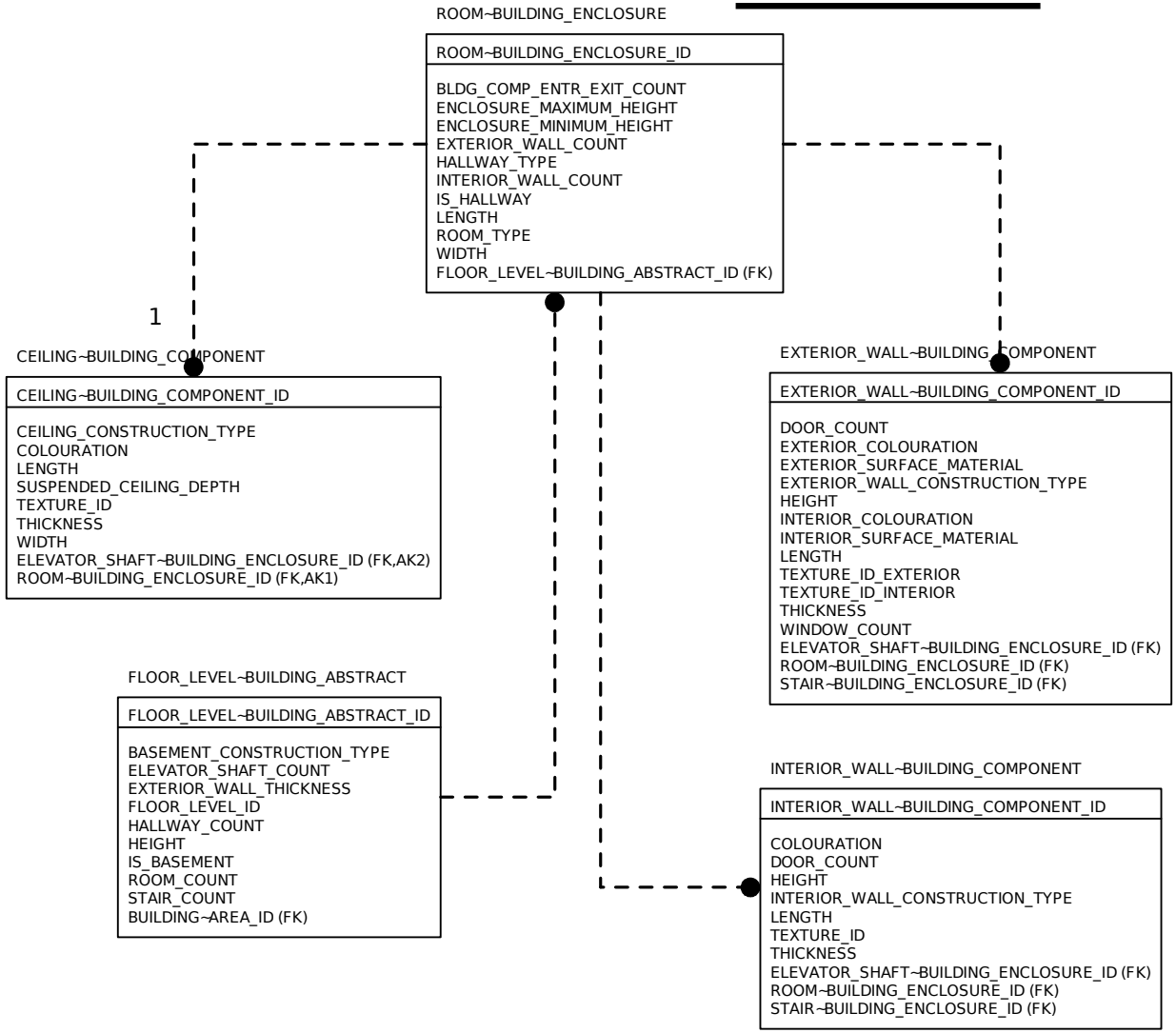
Existing EDM Support for Building Damage

- Specific damage features
  - Breach Hole
  - Wall Loophole
- Damage General
  - Applied to every feature
  - Features are localized, so homogeneous damage to localized features may be used to represent munitions-specific building-specific damage
    - Relationship between EXTERIOR WALL and ROOM requires the face of the BUILDING be decomposed into many EXTERIOR WALLs
- Vertical and Horizontal Load Bearing Capacity on surface features
- What else?
  - All windows on floors 3 – 5 broken
  - NE face of building completely destroyed
  - Stairwell physically intact but will collapse under use

… an Alternative to CSG

- Requirements: building configuration and building construction type
- UHRB Data Model vs. UHRB Data Base
  - A UHRB Data Base could be a relational database compliant with the schema of the UHRB Data Model
  - A table for each feature type
    - Records are feature instances
    - Fields are attribute values
    - Relationships (via PK/FK mechanism) capture configuration
    - Attributes capture construction types and an abstraction of geometry

UHRB Data Model



UHRB Data Base

ROOM~BUILDING_ENCLOSURE_ID	100000	100001	100002	100003	100004	100005
ENCLOSURE_MINIMUM_HEIGHT	3	3	3	3	3	3
NUMERIC_OBJECT_IDENTIFIER	1	2	3	4	5	6
LENGTH	3.048	4.2672	2.4	3.596	3	3.048
COUNT_QD_BY_BCT_FOR_ROOM	1, 2, 1, 0, 0, 0, 0	0, 1, 3, 0, 0, 0, 0	0, 2, 2, 0, 0, 0, 0	0, 2, 2, 0, 0, 0, 0	0, 1, 3, 0, 0, 0, 0	0, 2, 2, 0, 0, 0, 0
PASSAGE_BLOCKED	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
ENCLOSURE_MAXIMUM_HEIGHT	3	3	3	3	3	3
WIDTH	2.4	2.4	1.8288	3	2.5	3
LIGHTING_CHARACTERIZATION	BRIGHTLY_LIT	BRIGHTLY_LIT	LIGHTS_OFF	BRIGHTLY_LIT	LIGHTS_OFF	DIMLY_LIT
GENERAL_DAMAGE_FRACTION	0.0	0.0	0.0	0.0	0.0	0.0
FLOOR_LEVEL~BUILDING_ABSTRACT_ID	100000	100000	100000	100000	100000	100000

EXTERIOR_WALL~BUILDING_COMPONENT_ID	100000	100001	100002	100003	100004	100005	100006	100007	100008	100009
NUMERIC_OBJECT_IDENTIFIER	1	2	3	4	5	6	7	8	9	10
EXTERIOR_WALL_CONSTRUCTION_TYPE	BRICK	BRICK	BRICK	BRICK	BRICK	BRICK	BRICK	BRICK	BRICK	BRICK
INSULATION_PRESENT	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
EMISSIVITY_QUALIFIED BY_EM_BAND_AND_SUR_CAT										
COUNT_QD_BY_BCT_FOR_EXTERIOR_WALL	0, 1, 0, 0, 0	0, 0, 0, 1, 0	0, 0, 0, 1, 0	0, 0, 0, 2, 0	0, 0, 0, 1, 0	0, 0, 0, 0, 0	0, 1, 0, 0, 0	0, 0, 0, 1, 0	0, 0, 0, 1, 0	0, 0, 0, 1, 0
SURFACE_TEMPERATURE_QD_BY_SUR_CAT	25, 10	25, 10	25, 10	25, 10	25, 10	25, 10	25, 10	25, 10	25, 10	25, 10
GENERAL_DAMAGE_FRACTION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
THICKNESS	.1016	.1016	.1016	.1016	.1016	.1016	.1016	.1016	.1016	.1016
LENGTH	1.8288	2.4	3.048	4.2672	1.8288	2.4	1.8288	3	3.596	2.5
EXTERIOR_WALL_FORTIFICATION	NONE_PRESENT	NONE_PRESENT	NONE_PRESENT	NONE_PRESENT	NONE_PRESENT	NONE_PRESENT	NONE_PRESENT	NONE_PRESENT	NONE_PRESENT	NONE_PRESENT
SUR_MAT_TYPE_QD_BY_SUR_CAT	GYPSUM_WALLBOARD, MASONRY	GYPSUM_WALLBOARD, MASONRY	GYPSUM_WALLBOARD, MASONRY	GYPSUM_WALLBOARD, MASONRY	GYPSUM_WALLBOARD, MASONRY	GYPSUM_WALLBOARD, MASONRY	GYPSUM_WALLBOARD, MASONRY	GYPSUM_WALLBOARD, MASONRY	GYPSUM_WALLBOARD, MASONRY	GYPSUM_WALLBOARD, MASONRY
VERTICAL_LOAD_BEARING_CAPACITY										
COLOURATION_QD_BY_SUR_CAT	WHITE, BRICKRED	WHITE, BRICKRED	WHITE, BRICKRED	WHITE, BRICKRED	WHITE, BRICKRED	WHITE, BRICKRED	WHITE, BRICKRED	WHITE, BRICKRED	WHITE, BRICKRED	WHITE, BRICKRED
HEIGHT	3	3	3	3	3	3	3	3	3	3
ROOM~BUILDING_ENCLOSURE_ID		100000	100000	100001	100002	100002		100003	100003	100004
FLOOR_CRAWL_SPACE~BUILDING_ABSTRACT_ID										
HALLWAY~BUILDING_ENCLOSURE_ID	100000						100000			

EDM “Language”

- Appropriate not only for an abstract model of building configuration and construction type
  - But also for *describing* damage
    - E.g., South side exterior walls completely destroyed
    - All windows blown out
    - Breaching hole, diameter 1 meter, in specific wall
    - Horizontal load bearing capacity of stairs reduced by 50%
    - Vertical load bearing capacity of specific internal walls reduced to 500 kg / sq m
- More geometric attribution may be required in EDM
  - While EDM specifies dimensions of a wall and a related door, it does not say *where* the door is in the wall

Task 1 – Requirements

- Requirements Analysis / EDM Extensions
  - Which damage conditions are important to represent?
  - How are damage conditions represented by physics based models?
  - Collaboration with Footprint to Pathfinder
    - SWE API
    - Rubbling API
  - Extend UHRB EDM to describe additional damage conditions

CONOPS

- User defines change to a building instance using terminology of extended EDM
- UHRB Sim sends Environmental Interaction which abstractly describes the change to Repoly Service
- Repoly service generates add/modify/delete polygon information and returns to UHRB Sim
- UHRB Sim packages abstract and polygonal description into new Environmental Interaction
- Change received by ModStealth and JSAF DT Agents and integrated into runtime databases
  - JSAF DT Agent extensions to be funded by J9 JFCOM
- Goals
  - Latency of 2 sec or less
  - Changes to changes

Task 2 – UHRB Database

- Select existing polygonal model
  - VERTS, PEO STRI IDE or CFTDC, Ft. Benning MOUT
- Develop UHRB relational database for selected model
  - Complete repository of features, attributes, relationships and polygons defining the model

Task 3/4 – UHRB Sim

- Interfaces to UHRB database via SQL
- User requests structural damage effect and affected feature(s)
  - UHRB Sim generates request to Repoly Service
  - Repoly Service generates polygonal add/modify/delete instructions
    - Leverage existing Weiler Clipper
    - Accumulated damage an issue
    - 3D polygons in VRML or X3D
  - UHRB Sim packages feature and polygonal changes into an Environmental Interaction
    - Published on RTI
- Extend DT BOM and FOM

Task 5/6 – New DT Agents

- DT Agent required for UHRB Database
  - Add, modify, delete features, attributes, relationships, polygons in the relational database
- Extend DT Agent for ModStealth
  - Repolygonization of building models (visual)

Expectations of Transition Customers

- OOS to develop DT Agent for runtime format
  - Including extensions to UHRB EDM and FOM
  - OOS planning to integrate DT Architecture next FY
- J9 to extend CTDB DT Agent for MES structures

Clarification

- Original White Paper proposed to integrate physics-based damage models
  - At significantly higher cost
- Planned development will be compatible with the damage descriptions of physics models
  - But will not integrate them
- No heuristic collateral damage simulation proposed
  - All damage descriptions user defined

Help Desired

- Quality time with Footprint to Pathfinder
- Identification and participation of SMEs
  - Combined Arms MOUT Task Force (CAMTF)?
  - VIRTE Close Quarters Combat SMEs?
- ERDC World Construction Practices Database
  - Would like to track detailed progress
- AMSAA UTZ Templates (D. Fordyce)
  - Nothing yet on building interiors